# Laboratory Evaluation

# Alphasense OPC-N2 PM Sensor

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

# Background

Three **Alphasense OPC-N2** (units IDs: 216, 222, 308) were field-tested at the SCAQMD Rubidoux fixed ambient monitoring station (07/10/2015 to 08/10/2015) under ambient weather conditions. Now, three new OPC-N2 (units ID: 0508, 1202, 1207) have been evaluated in the SCAQMD Chemistry Laboratory under controlled PM concentration, temperature, and relative humidity.

**OPC-N2 PMS1003 (*3 units tested*):**
- Particle sensors (optical; non-FEM)
- Each unit measures: $PM_{1.0}$, $PM_{2.5}$, $PM_{10}$ mass concentration ($\mu g/m^3$)
- Unit cost: ~$450
- Time resolution: 1.4 to 20 seconds
- Units IDs: 0508, 1202, 1207

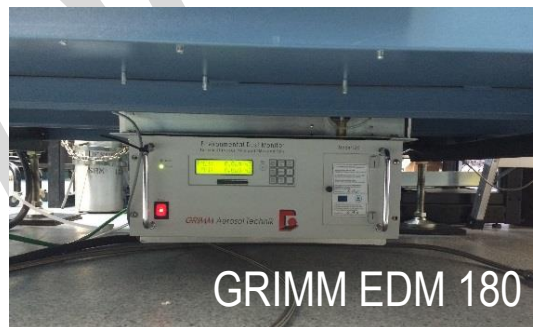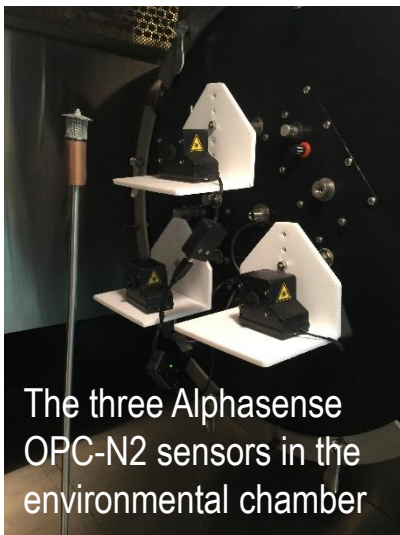**GRIMM EDM 180 (*ref. method for $PM_{1.0}$, $PM_{2.5}$ mass*):**
- Optical particle counter
- FEM $PM_{2.5}$
- Uses proprietary algorithms to calculate total PM, $PM_{2.5}$, and $PM_{1.0}$ mass conc. from particle number measurements
- Cost: ~$25,000

**TSI APS 3321 (*ref. method for $PM_{10}$ mass*):**
- Aerodynamic particle sizer
- Measures particles from 0.5 to 20 μm
- Uses a patented, double-crest optical system for unmatched sizing accuracy
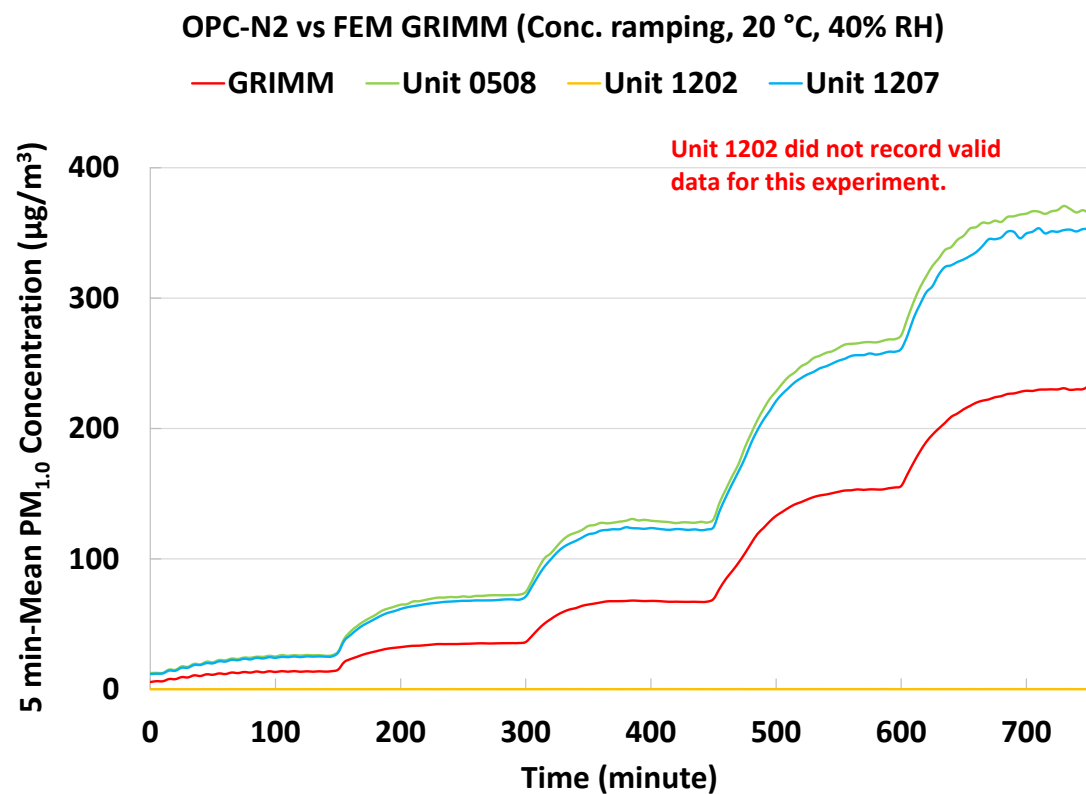- Cost: ~$50,000

# Evaluation results guideline

- OPC-N2 *v.s.* GRIMM $PM_{1.0}$ mass concentration

- OPC-N2 *v.s.* GRIMM $PM_{2.5}$ mass concentration

- OPC-N2 *v.s.* APS *v.s.* GRIMM $PM_{10}$ mass concentration



The three Alphasense OPC-N2 sensors in the environmental chamber



GRIMM EDM 180



TSI APS 3321

# Evaluation results for OPC-N2 PM$_{1.0}$ mass

## OPC-N2 *vs* GRIMM

# Coefficient of Determination: OPC-N2 $PM_{1.0}$ vs GRIMM

**OPC-N2 vs FEM GRIMM (Conc. ramping, 20 °C, 40% RH)**

— GRIMM — Unit 0508 — Unit 1202 — Unit 1207

Unit 1202 did not record valid data for this experiment.

*y-axis:* 5 min-Mean $PM_{1.0}$ Concentration ($\mu g/m^3$) — 0, 100, 200, 300, 400

*x-axis:* Time (minute) — 0, 100, 200, 300, 400, 500, 600, 700

**Linearity of Unit Response**

$PM_{1.0}$ mass ($\mu g/m^3$) 20 °C, 40% RH
1-min mean data

$y = 0.64x - 7.80$
$R^2 = 0.99$

*y-axis:* FEM GRIMM — 0, 100, 200, 300, 400

*x-axis:* Avg. of units 0508 and 1207 — 0, 100, 200, 300, 400

- OPC-N2 units 0508 and 1207 showed excellent correlation with GRIMM $PM_{1.0}$ measurement data ($R^2 = 0.99$) between 0-230 $\mu g/m^3$.

- The OPC-N2 units overestimated the GRIMM $PM_{1.0}$ concentration.

- Over the full $PM_{1.0}$ concentration range tested (0-230 $\mu g/m^3$), OPC-N2 units 0508 and 1207 tracked well the diurnal variations as recorded by the GRIMM.

- For this experiment, Unit 1202 did not record valid measurements. Later, Unit 1202 resumed normal data logging by itself.

# OPC-N2 PM$_{1.0}$ Accuracy

- Accuracy (20 °C and 40% RH)

| Steady State (#) | Sensor mean (µg/m³) | GRIMM (µg/m³) | Accuracy (%) |
|---|---|---|---|
| 1 | 25.6 | 13.7 | 13.4 |
| 2 | 70.6 | 35.3 | 0.3 |
| 3 | 125.2 | 67.2 | 13.8 |
| 4 | 262.8 | 153.9 | 29.2 |
| 5 | 360.2 | 230.7 | 43.8 |

- The OPC-N2 units showed low to moderate accuracy levels compared to GRIMM PM$_{1.0}$ over the concentration range of 0-230 µg/m³. Accuracy ranged from 0.3% to 43.8%. In general, OPC-N2 units overestimated the PM$_{1.0}$ mass measured by GRIMM.

# OPC-N2 PM$_{1.0}$ Data Recovery & Intra-model Variability

- Data recovery for PM$_{1.0}$ mass concentration from 0508, 1202, and 1207 was 100%, 42.4%, and 100%.

- Low PM$_{1.0}$ measurement variations were observed between the units 0508 and 1207. Unit 1202 did not record valid data during the intra-model variability test.
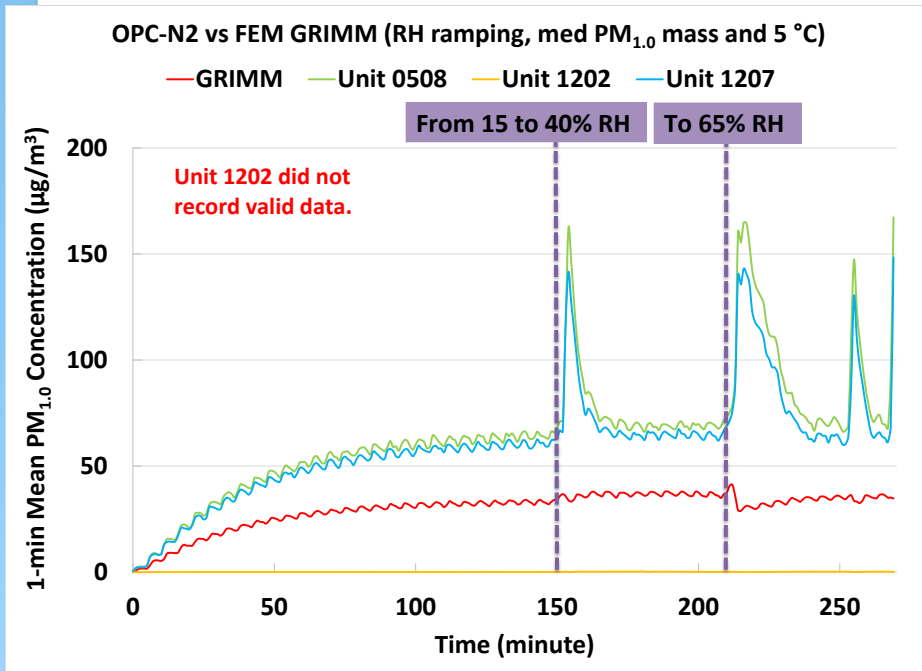
# OPC-N2 PM$_{1.0}$ Precision

- Precision (%, Effect of PM$_{1.0}$ conc., temperature and relative humidity)
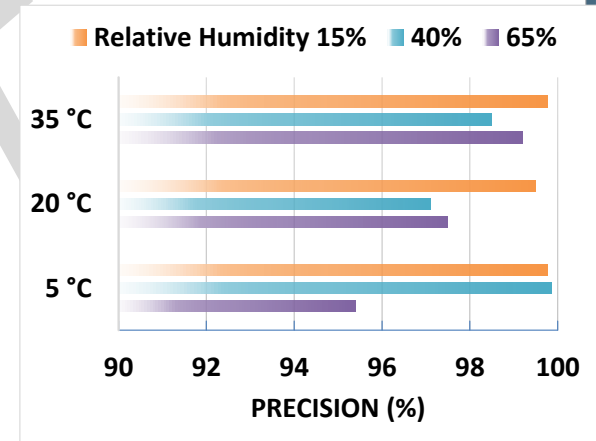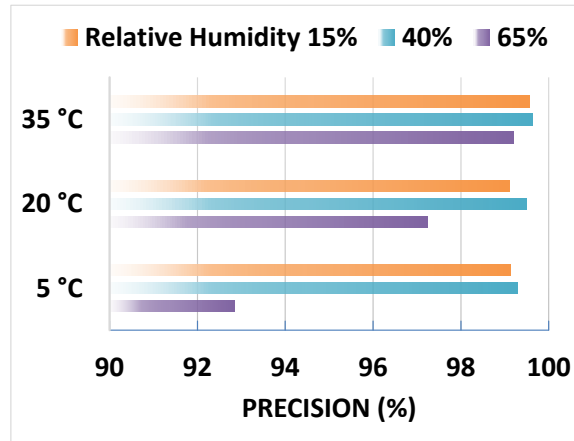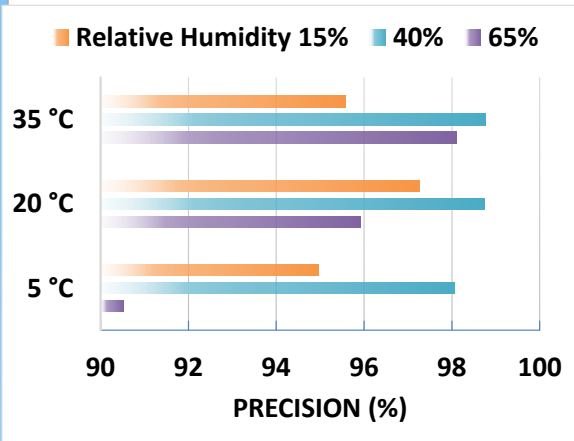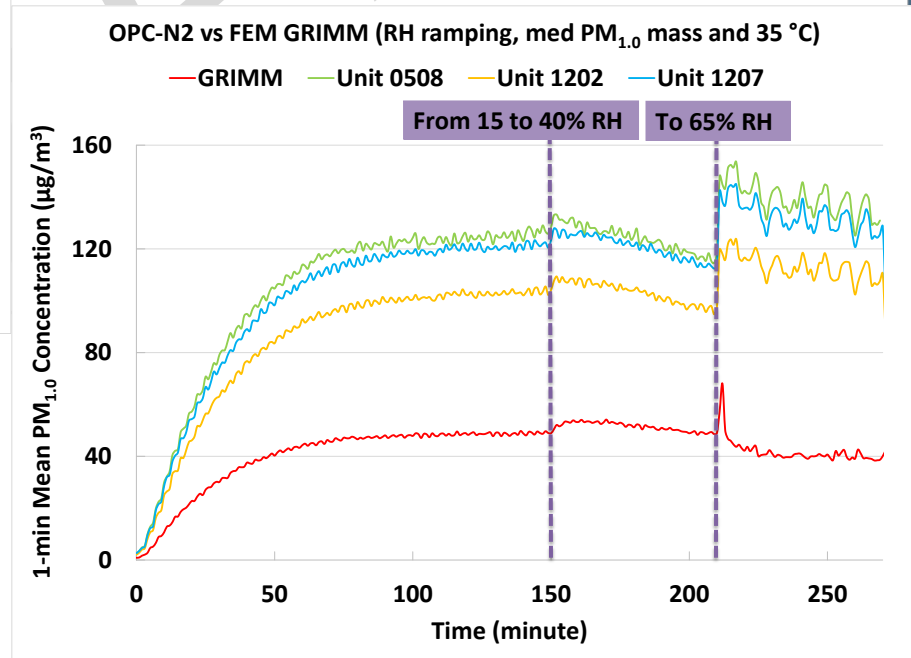


- Overall, the OPC-N2 units showed high precision for most of T, RH, and PM conc. combinations, except for very high humidity conditions at 5, and 20 °C.

- GRIMM's precision was high across all conditions.

*100% represents high precision.

# OPC-N2 PM$_{1.0}$ Climate Susceptibility

**OPC-N2 vs FEM GRIMM (RH ramping, med PM$_{1.0}$ mass and 5 °C)**

— GRIMM  — Unit 0508  — Unit 1202  — Unit 1207

From 15 to 40% RH    To 65% RH

Unit 1202 did not record valid data.

Low Temp – RH ramping (medium conc.)

**OPC-N2 vs FEM GRIMM (RH ramping, med PM$_{1.0}$ mass and 35 °C)**

— GRIMM  — Unit 0508  — Unit 1202  — Unit 1207

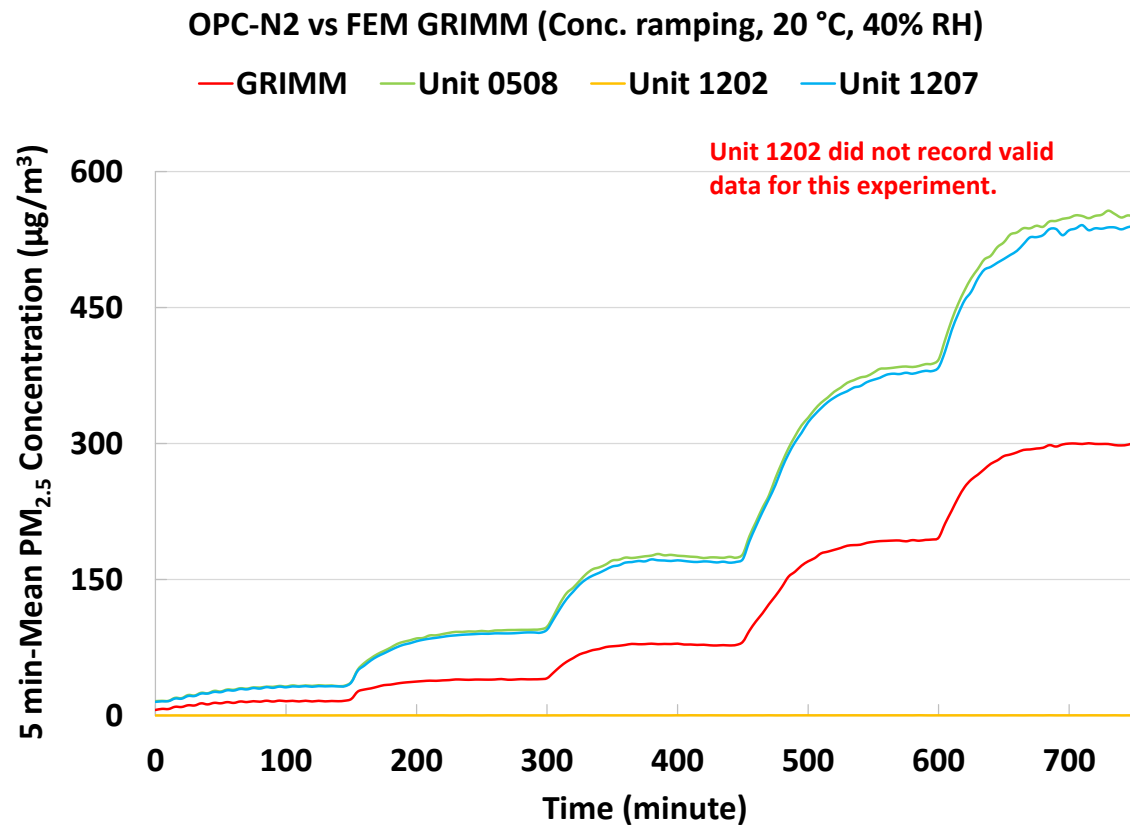From 15 to 40% RH    To 65% RH

High Temp – RH ramping (medium conc.)

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# Evaluation results for OPC-N2 PM$_{2.5}$ mass

OPC-N2 *vs* GRIMM

# Coefficient of Determination: OPC-N2 PM$_{2.5}$ vs FEM GRIMM

**OPC-N2 vs FEM GRIMM (Conc. ramping, 20 °C, 40% RH)**

— GRIMM    — Unit 0508    — Unit 1202    — Unit 1207

Unit 1202 did not record valid data for this experiment.

*(Chart: 5 min-Mean PM$_{2.5}$ Concentration (µg/m³) vs Time (minute), y-axis 0–600, x-axis 0–700)*

**Linearity of Unit Response**

PM$_{2.5}$ mass (µg/m³) 20 °C, 40% RH
1-min mean data

$y = 0.56x - 8.98$
$R^2 = 0.99$

*(Scatter plot: FEM GRIMM (y-axis 0–600) vs Avg. of units 0508 and 1207 (x-axis 0–600))*

- Over the full PM$_{2.5}$ concentration range tested (0-300 µg/m³), OPC-N2 units 0508 and 1207 tracked well the diurnal variations as recorded by the FEM GRIMM.

- For this experiment, Unit 1202 did not record valid measurements. Later, Unit 1202 resumed normal data logging by itself.
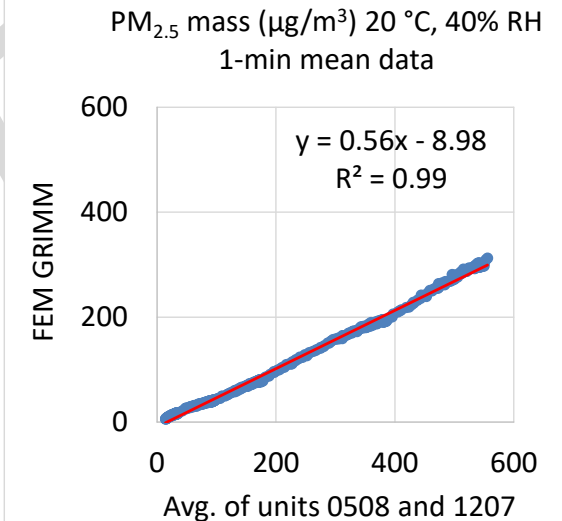
- OPC-N2 units 0508 and 1207 showed excellent correlation with FEM GRIMM PM$_{1.0}$ measurement data ($R^2$ = 0.99) between 0-300 µg/m³.

- The OPC-N2 units overestimated the FEM GRIMM PM$_{2.5}$ mass concentration.

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# OPC-N2 PM$_{2.5}$ Accuracy

- Accuracy (20 °C and 40% RH)

| Steady State (#) | Sensor mean (µg/m³) | FEM (µg/m³) | Accuracy (%) |
|---|---|---|---|
| 1 | 32.6 | 16.0 | -3.9 |
| 2 | 93.0 | 39.9 | -33.2 |
| 3 | 171.8 | 77.8 | -20.9 |
| 4 | 382.6 | 193.3 | 2.1 |
| 5 | 545.8 | 299.5 | 17.8 |

- The OPC-N2 units showed low accuracy compared to FEM GRIMM PM$_{2.5}$ over the concentration range tested (0-300 µg/m³). Accuracy varied from -33.2% to 17.8%. At low to medium PM$_{2.5}$ concentrations, the sensors overestimated the FEM GRIMM by more than 100%, therefore, the calculated accuracy generated negative values.

# OPC-N2 PM$_{2.5}$ Data Recovery & Intra-model Variability

- Data recovery for PM$_{2.5}$ mass concentration from 0508, 1202, and 1207 was 100%, 42.4%, and 100%.

- Low PM$_{2.5}$ measurement variations were observed between the units 0508 and 1207. Unit 1202 did not record valid data during the intra-model variability test.

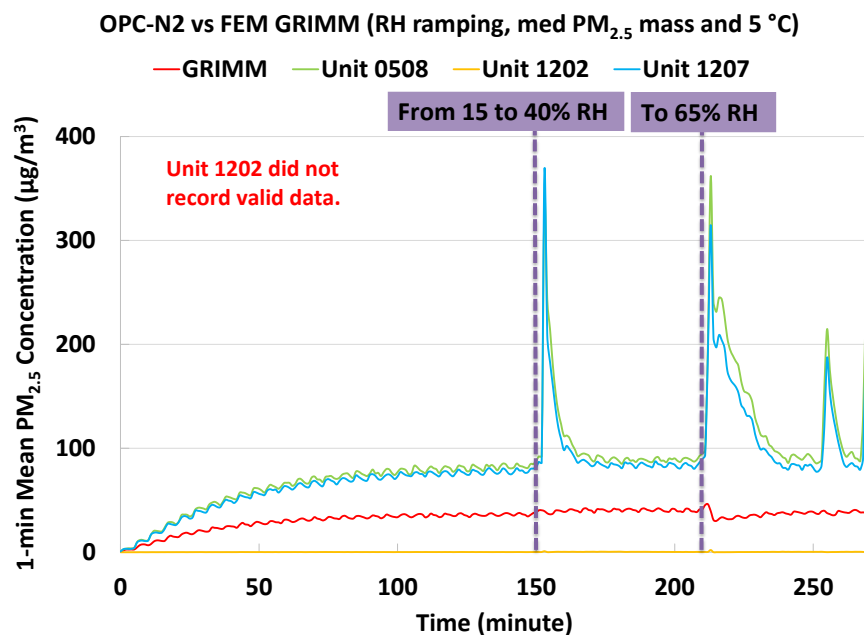# OPC-N2 PM$_{2.5}$ Precision

- Precision (%, Effect of PM$_{2.5}$ conc., temperature and relative humidity)
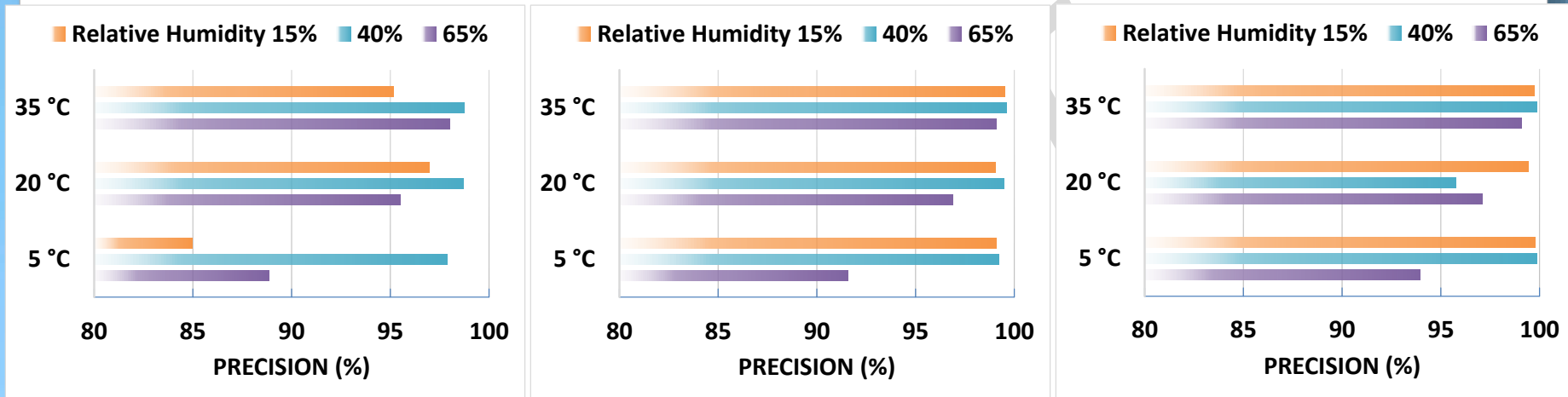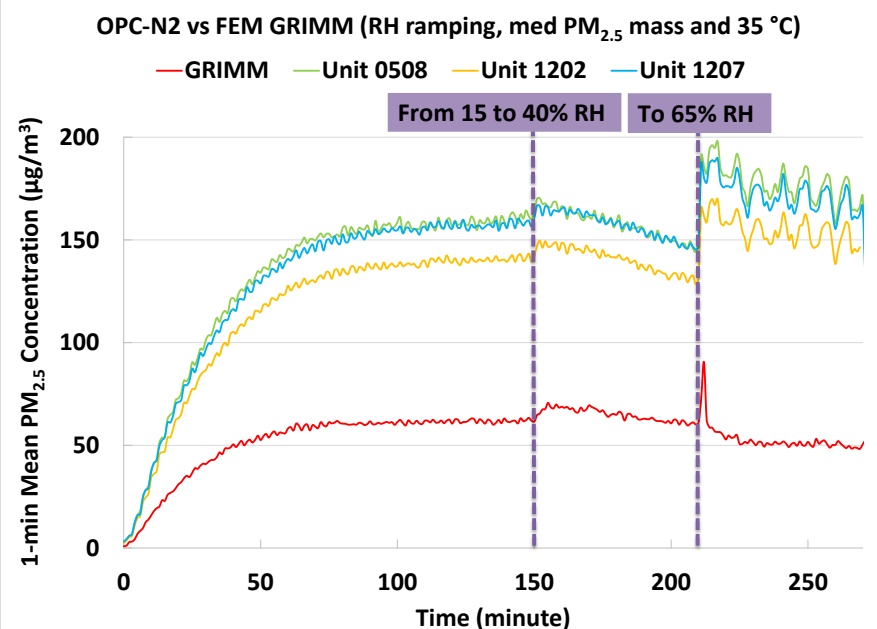


- Overall, the OPC-N2 units showed high precision for most of T, RH, and PM conc. combinations, except for high humidity levels at 5 °C, and also at 5 °C/15% RH.

- FEM GRIMM's precision was also high across all conditions.

*100% represents high precision.

# OPC-N2 PM$_{2.5}$ Climate Susceptibility

**OPC-N2 vs FEM GRIMM (RH ramping, med PM$_{2.5}$ mass and 5 °C)**

— GRIMM  — Unit 0508  — Unit 1202  — Unit 1207

From 15 to 40% RH   To 65% RH

Unit 1202 did not record valid data.

Low Temp – RH ramping (medium conc.)

**OPC-N2 vs FEM GRIMM (RH ramping, med PM$_{2.5}$ mass and 35 °C)**

— GRIMM  — Unit 0508  — Unit 1202  — Unit 1207

From 15 to 40% RH   To 65% RH
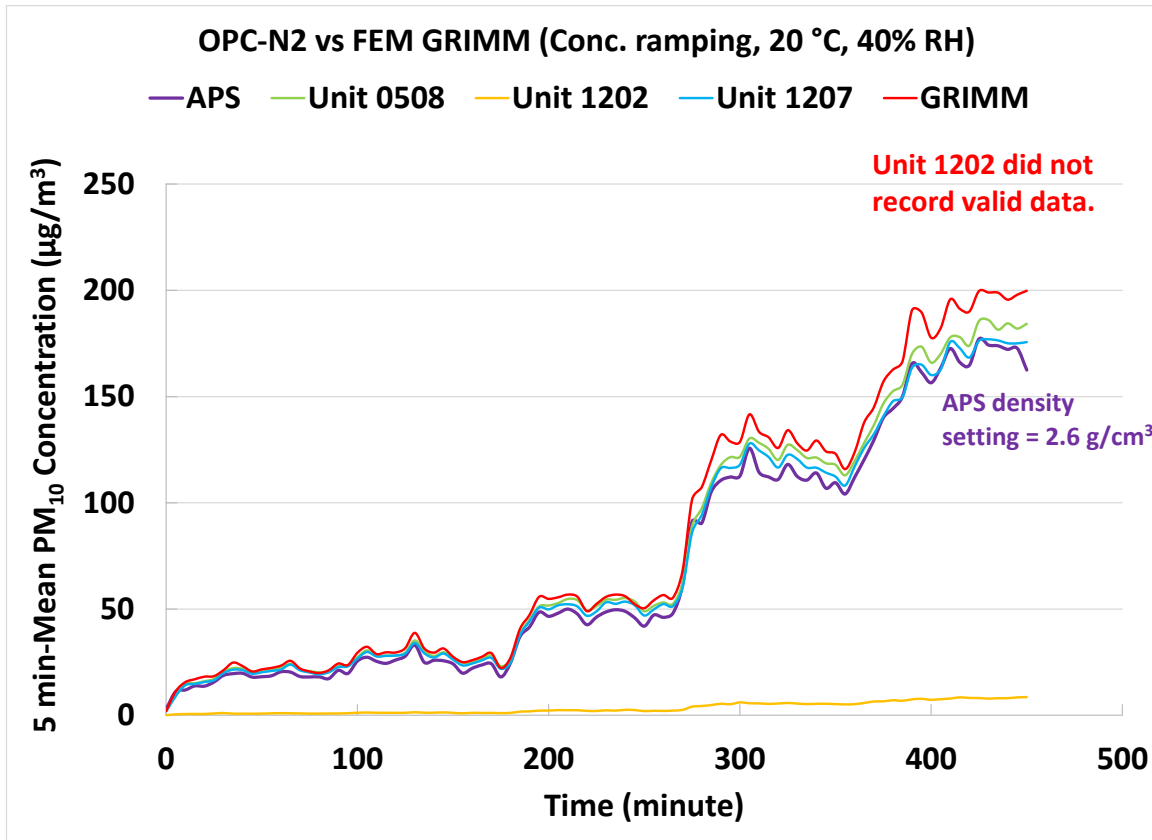
High Temp – RH ramping (medium conc.)

# Discussion

- **Accuracy**: Overall, the OPC-N2 units have low accuracy, compared to the GRIMM $PM_{1.0}$ and $PM_{2.5}$ in the tested range. The OPC-N2 units overestimated the $PM_{1.0}$ and $PM_{2.5}$ mass measured by GRIMM. (refer to slide 6 and 11).

- **Precision**: The OPC-N2 units have high precision for most of tested combinations (PM concentrations, T and RH), except at high humidity levels at 5 °C. (refer to slide 7 and 12)

- **Intra-model variability**: Low intra-model variability was observed between units 0508 and 1207. Unit 1202 had significant data loss, and did not record valid data during the intra-model variability experiment.

- **Data Recovery:** Data recovery from 0508, 1202, and 1207 was 100%, 42.4%, and 100%. Unit 1202 did not record valid data for a period of time, but later it resumed normal performance on its own.

- **Linearity of sensor response**: OPC-N2 units showed excellent correlation/linear response with the corresponding GRIMM $PM_{1.0}$ and $PM_{2.5}$ measurement data ($R^2$ = 0.99 and 0.99, respectively) for mass concentration range between 0 and 300 $\mu g/m^3$. (refer to slides 5 and 10)

- **Climate susceptibility**: From the laboratory studies, low temperature and high humidity affected the precision of OPC-N2 units. (refer to slide 7 and 12)

# Evaluation results for OPC-N2 PM$_{10}$ mass

## OPC-N2 *vs* APS *vs* GRIMM

# Coefficient of Determination: OPC-N2 PM$_{10}$ vs GRIMM vs APS

**Linearity of Unit Response**

**OPC-N2 vs FEM GRIMM (Conc. ramping, 20 °C, 40% RH)**

— APS — Unit 0508 — Unit 1202 — Unit 1207 — GRIMM

**Unit 1202 did not record valid data.**

**APS density setting = 2.6 g/cm$^3$**

PM$_{10}$ mass (µg/m$^3$) 20 °C, 40% RH
1-min mean data

$y = 0.97x - 1.72$
$R^2 = 0.99$

APS PM$_{10}$

Avg. of units 0508 and 1207

PM$_{10}$ mass (µg/m$^3$) 20 °C, 40% RH
1-min mean data

GRIMM PM$_{10}$

$y = 1.10x - 1.44$
$R^2 = 0.99$

Avg. of units 0508 and 1207

- Over the full PM$_{10}$ concentration range tested (0-200 µg/m$^3$), the OPC-N2 units tracked well the diurnal variations as recorded by the APS and GRIMM.
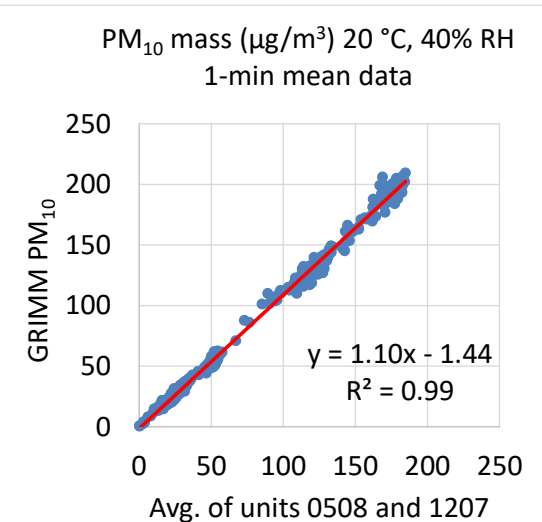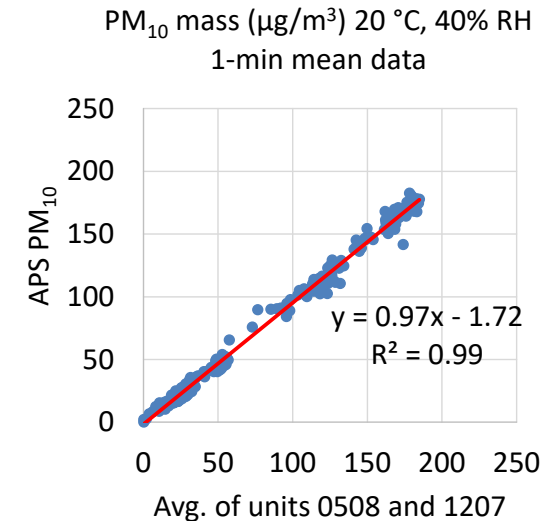
# OPC-N2 vs APS: Accuracy

- Accuracy* (20 °C and 40% RH)

| Steady State (#) | Sensor mean ($\mu g/m^3$) | APS-2.6 ($\mu g/m^3$) | Accuracy (%) |
|:---:|:---:|:---:|:---:|
| 1 | 18.7 | 21.3 | 86.3 |
| 2 | 22.0 | 25.3 | 85.1 |
| 3 | 46.5 | 51.6 | 89.1 |
| 4 | 109.3 | 116.3 | 93.6 |
| 5 | 172.5 | 179.6 | 95.9 |

- The OPC-N2 units had high accuracy when compared to APS. The units' accuracy ranges from 85.1% to 95.9%.

# OPC-N2 $PM_{10}$ Data Recovery & Intra-model Variability

- Data recovery for $PM_{10}$ mass concentration from 0508, 1202, and 1207 was 96.8%, 9.5%, and 96.8%.

- Low $PM_{10}$ measurement variations were observed between the units 0508 and 1207. Unit 1202 did not record valid data during the intra-model variability test.
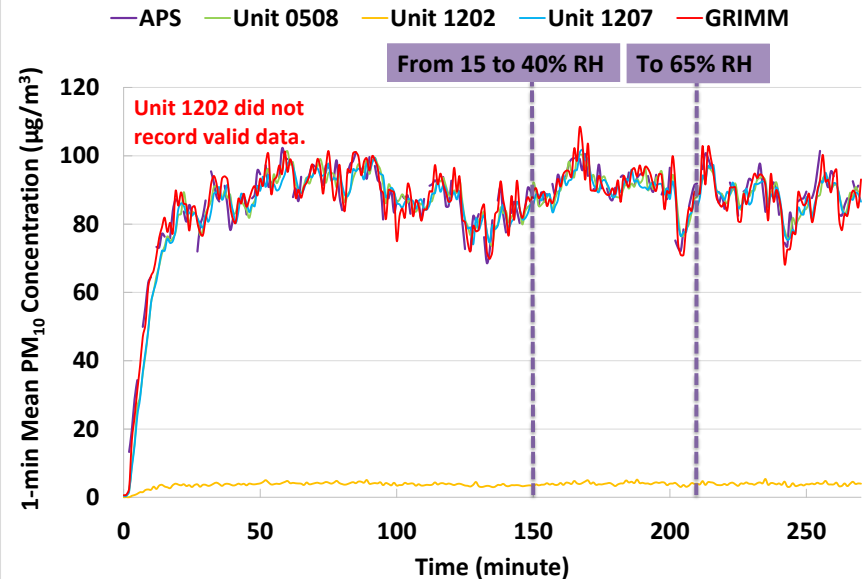
# OPC-N2 PM$_{10}$ Climate Susceptibility
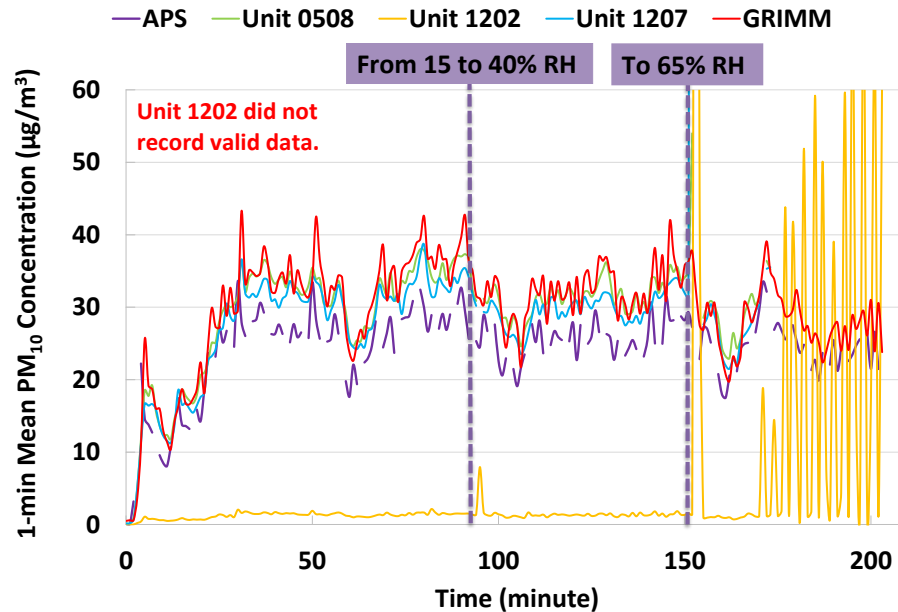


Low Temp – RH ramping
(medium conc.)

High Temp – RH ramping
(medium conc.)

# Discussion

- **Accuracy**: The OPC-N2 units had high accuracy when compared to APS. The units' accuracy ranges from 85.1% to 95.9%. (refer to slide 17)

- **Precision**: Due to the nature of Arizona test dust, the aerosol concentration showed some variability in the chamber, therefore, the precision could not be estimated. At high humidity levels at 5 °C the OPC-N2 units recorded out of range $PM_{10}$ concentrations in thousands of micrograms per cubic meter. (refer to slide 18)

- **Intra-model variability**: Low intra-model variability was observed between units 0508 and 1207. Unit 1202 had significant data loss, and did not record valid data during the intra-model variability experiment.

- **Data Recovery:** Data recovery for $PM_{10}$ mass concentration from 0508, 1202, and 1207 were 96.8%, 9.5%, and 96.8%.

- **Linearity of sensor response**: OPC-N2 units showed excellent correlation/linear response with the corresponding APS $PM_{10}$ ($R^2$ = 0.99) and GRIMM $PM_{10}$ ($R^2$ = 0.99). (refer to slide 16)

- **Climate susceptibility**: At low temperature and high humidity levels, the OPC-N2 units recorded out of range $PM_{10}$ mass concentrations.